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6G BRAINS

# SMART FACTORIES: TODAY, TOMORROW AND THE DAY AFTER TOMORROW

**WIRELESS INTELLIGENT NETWORKS 2021**
23.06.2021

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**Demography:**
2030 average expectation of life 81,5 years in Germany

Society

**Urbanization:**
70% of the population lives in cities by 2050

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**Digitization:** Bandwidth for data transfer doubles roughly every 21 month

## Technology

**Connectivity:** 125 billion connected things by 2030

**AI & Automation:** 15,7 trillion $ is the expected contribution of AI to worldwide economy until 2030

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**Climate:** The probability that global warming will be limited to 2 degree is very low
Environment
**Energy:** 30% more energy consumption worldwide until 2035



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# Important changes in recent years

Low priced **sensors** available

**Data mining**: Analyse big data close to real-time

**Internet** is available worldwide

Increase in soft-/hardware **usability**

**CPU** is available cheap and unlimited

Performance advantages by **decentralized networking**

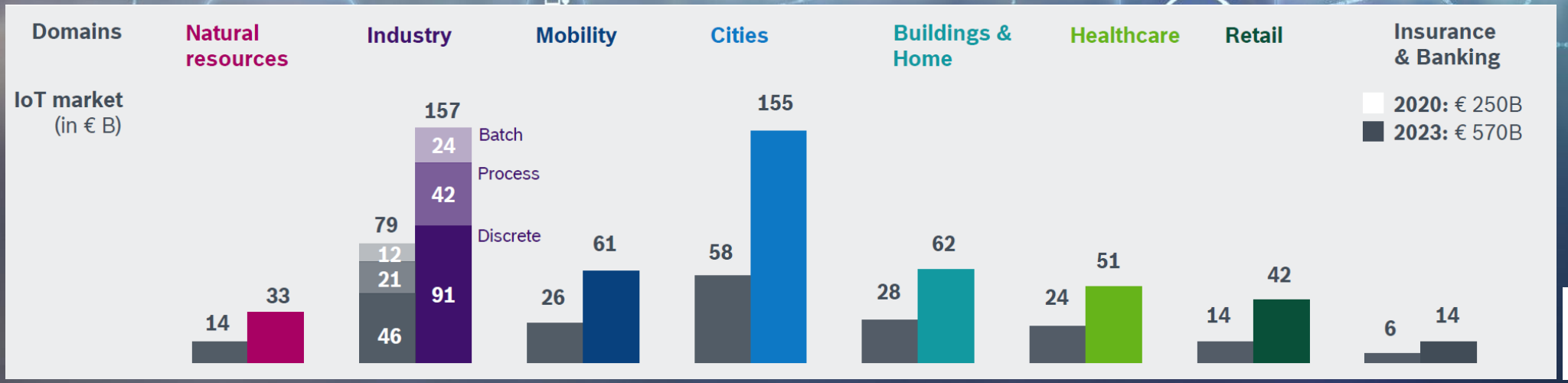
Worldwide **GPS** localization is possible

**Storage** is available cheap and unlimited

# Internet of things


https://youtu.be/uaeADiepfXk

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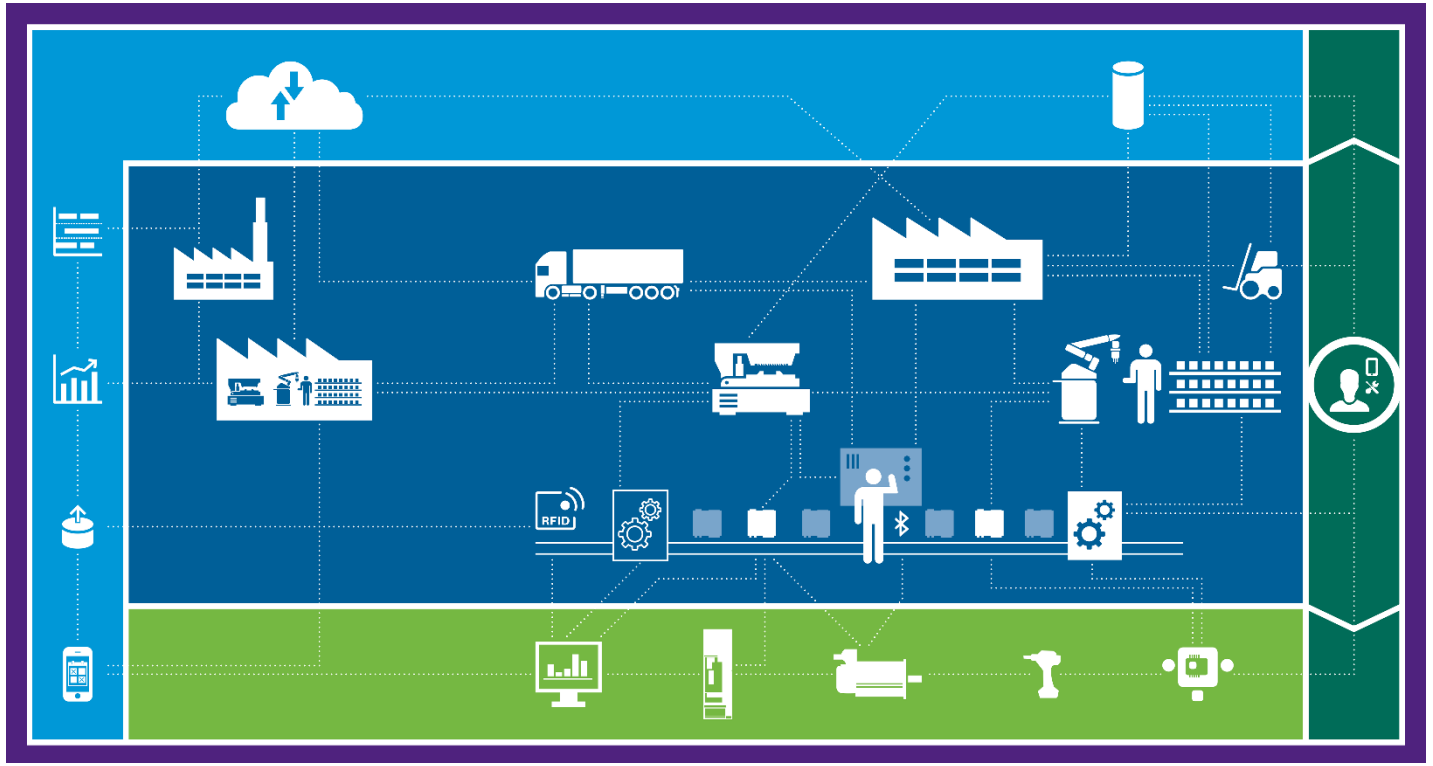
# Industrial IoT




## Software Solutions

*The element that links all modules and subsystems along the value stream with people and third-party systems.*

## Services and Consulting

*A broad range of services and consulting including collaborative projects to test new business models.*

## Logistics and Manufacturing

*Solutions that connect machines and whole manufacturing lines to value-creation networks.*

## Field Level Equipment

*Components, modules and systems that enable the integration of equipment into networked i4.0 environments.*

**Key enablers for IIoT:**

- Cyber-physical systems
- Edge computing
- AI/ML
- WLAN, RFID
- Mobile technologies: 5G/B5G
- Big data
- 3D printing
- Advanced robotics
- Cloud computing

# Agenda

- Smart Factories: TODAY
- Smart Factories: TOMORROW
- Smart Factories: THE DAY AFTER TOMORROW

# SMART FACTORIES: TODAY

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# Smart Factories: Today

Industrial Control

Mobile Robot

(Wireless) Sensor Networks

Novel Assistance Systems

## Advances

- Virtualization (control, compute, network)
- Highly connected (mostly wired)
- Big data
- Novel wireless technologies (4G/5G, WiFi5, RFID, BLE, etc.)
- Edge/Fog/Cloud computing
- Introduction of AI/ML

## Challenges

- Fixed production lines, solitary products & solutions
- Poor support of safety concepts in novel technologies
- Integration in multi-tier cloud architecture / interplay with cloud
- Automated provisioning/partitioning of apps
- Interface between private & public infrastructure
- Shift from technology- to customer-centric approach

Pictures source: http://www.bosch-presse.de/pressportal/de/de/news/




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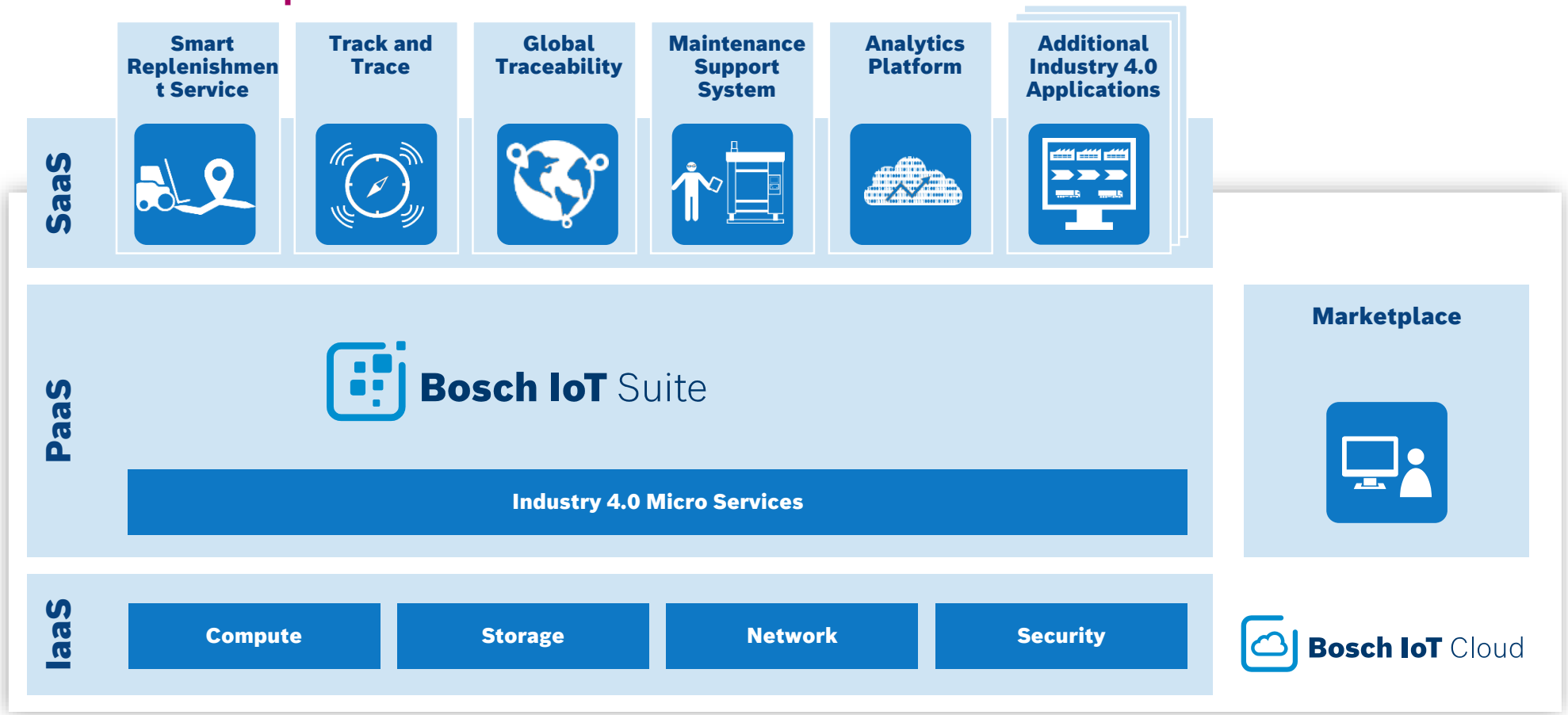
# Smart Factories: Today
## IIoT Cloud Example




IaaS / PaaS / SaaS = Infrastructure / Platform / Software as a Service


Bosch Research, Dr. Alexander Artemenko | 2021

# Smart Factories: Today
## Logistics with RFID


**30%** reduction of stock in processes

**10%** efficiency increase in processes

LOGISTIK AWARD 2014
VDA Verband der Automobilindustrie



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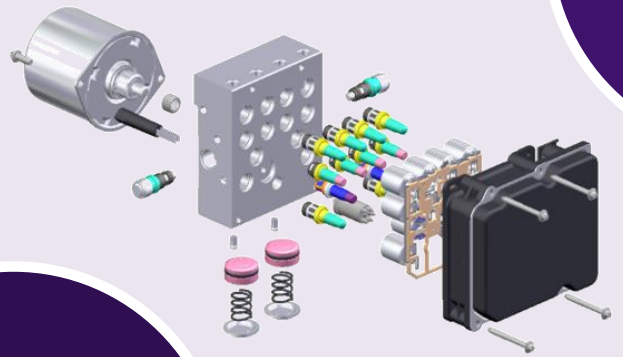
# Smart Factories: Today
## Production quality: Smart tightening

# Smart Factories: Today
## Smart Adaptive Testing



~10% cycle time reduction

~10% output increase per day

Elimination of errors & bottlenecks

# Smart Factories: Today
## i4.0 in an entire line – example Homburg

**30%** stock reduction, no setup

Up to **0.5** mio € savings year / line

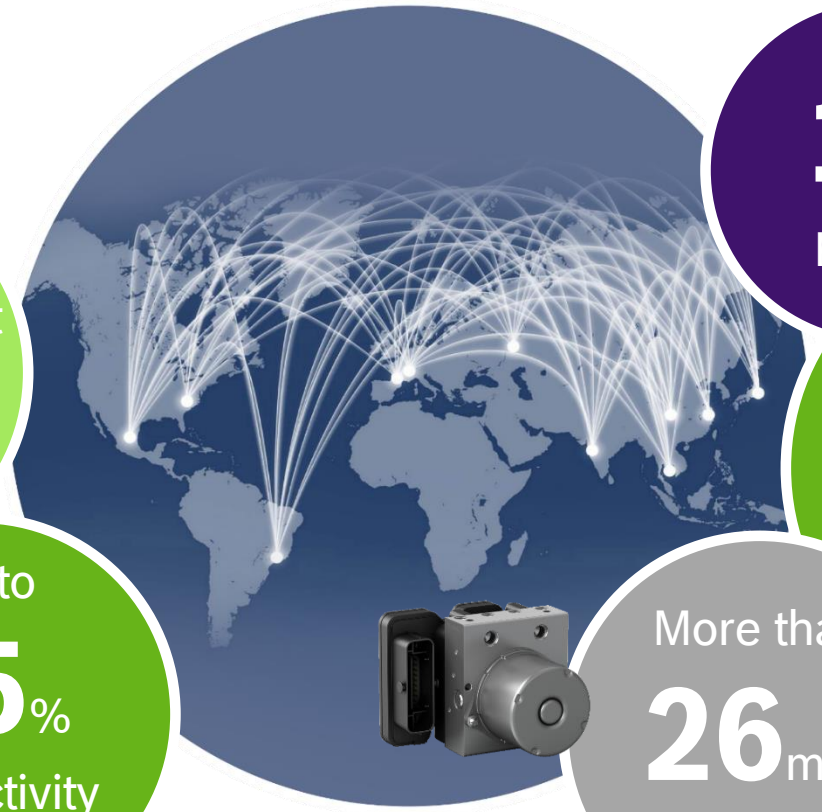
**10%** output increase


**People as key players**

INDUSTRIE 4.0 @ INTELLIGENTE FABRIK

# Smart Factories: Today

## i4.0 in an International Production Network – example ABS / ESP



**11** plants

**>5000** machines connected

More than **26** mio. units / year

Up to **25**% productivity increase

Worldwide plant benchmarking based on MES

# SMART FACTORIES: TOMORROW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# Smart Factories: TOMORROW


## Advances

- Fully virtualized (devices, products, control, compute, network)
- Fully connected (wired and wireless)
- Compute everywhere
- Flexible customer-centric production
- Improved downtime
- Advanced AI/ML
- High mobility

## Challenges

- Multi-tier connectivity and compute platforms
- Vast cloud native landscape
- Embedded compute
- Support in network QoS, highly deterministic traffic
- Support of brown field
- Private & public infrastructure mix
- Focus on the customer needs first

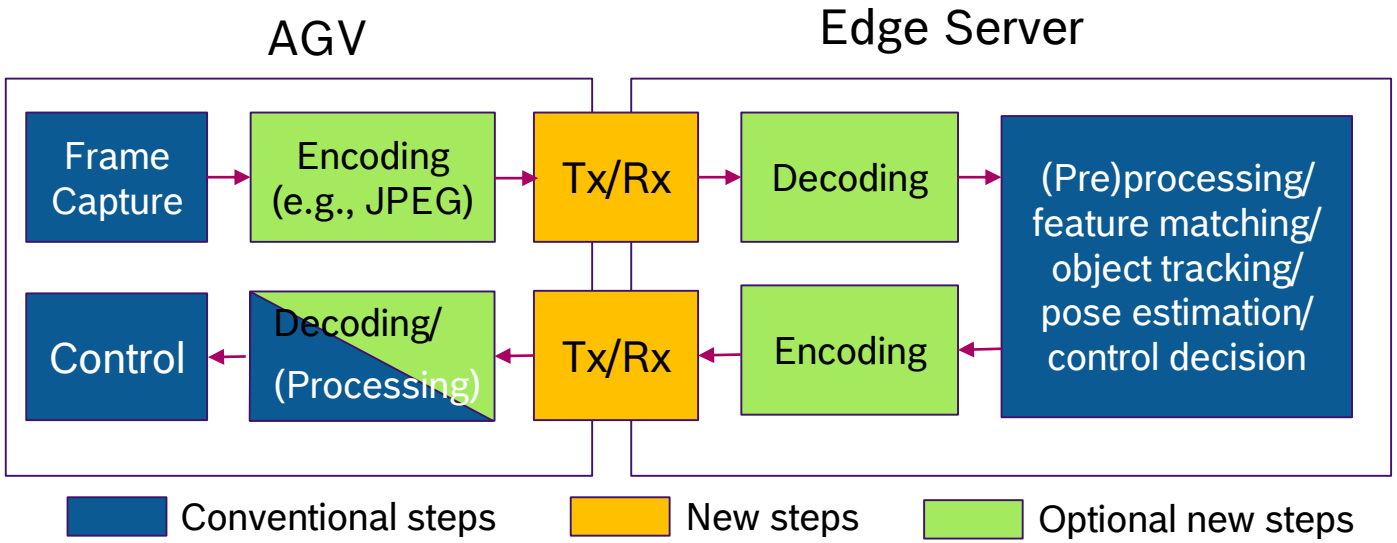
# Smart Factories: TOMORROW
## Video Offloading to Zero-Downtime Edge Cloud

**Requirements**

- Motion-to-Photon latency < 100 ms
  - High throughput (>500 Mbps), short latency
- Costs, size and weight constraints
- Use by multiple collaborating users simultaneously

**Benefits of offloading:**

- Offloading – enabling complex video processing for resource-constrained devices
- Video processing as a service
- Server-side rendering of complex 3D models
- Enabler for collaborative and context-sensitive video processing




Pictures source: http://www.bosch-presse.de/pressportal/de/de/news/

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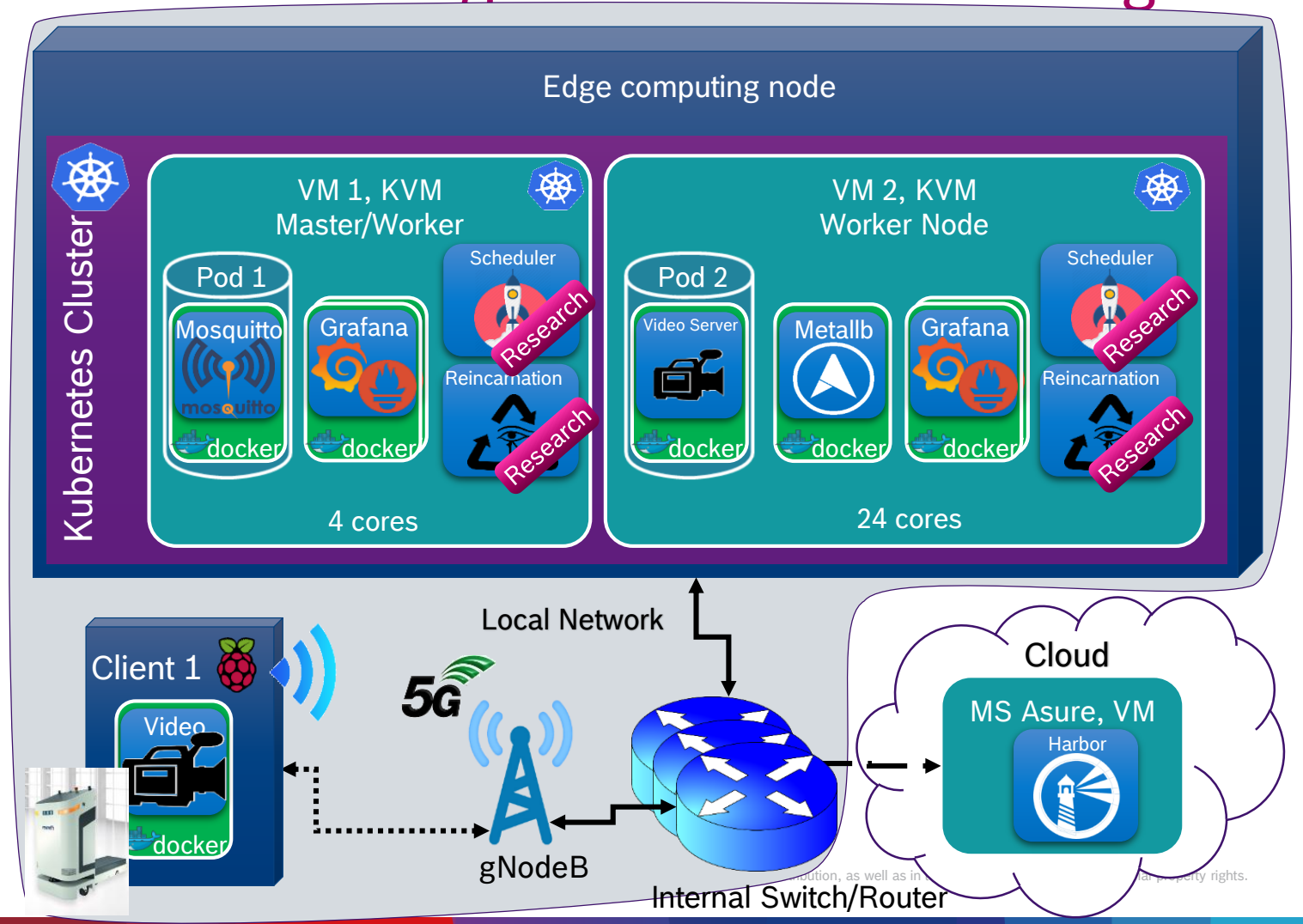
# Smart Factories: TOMORROW

## Video Offloading to Zero-Downtime Edge Cloud

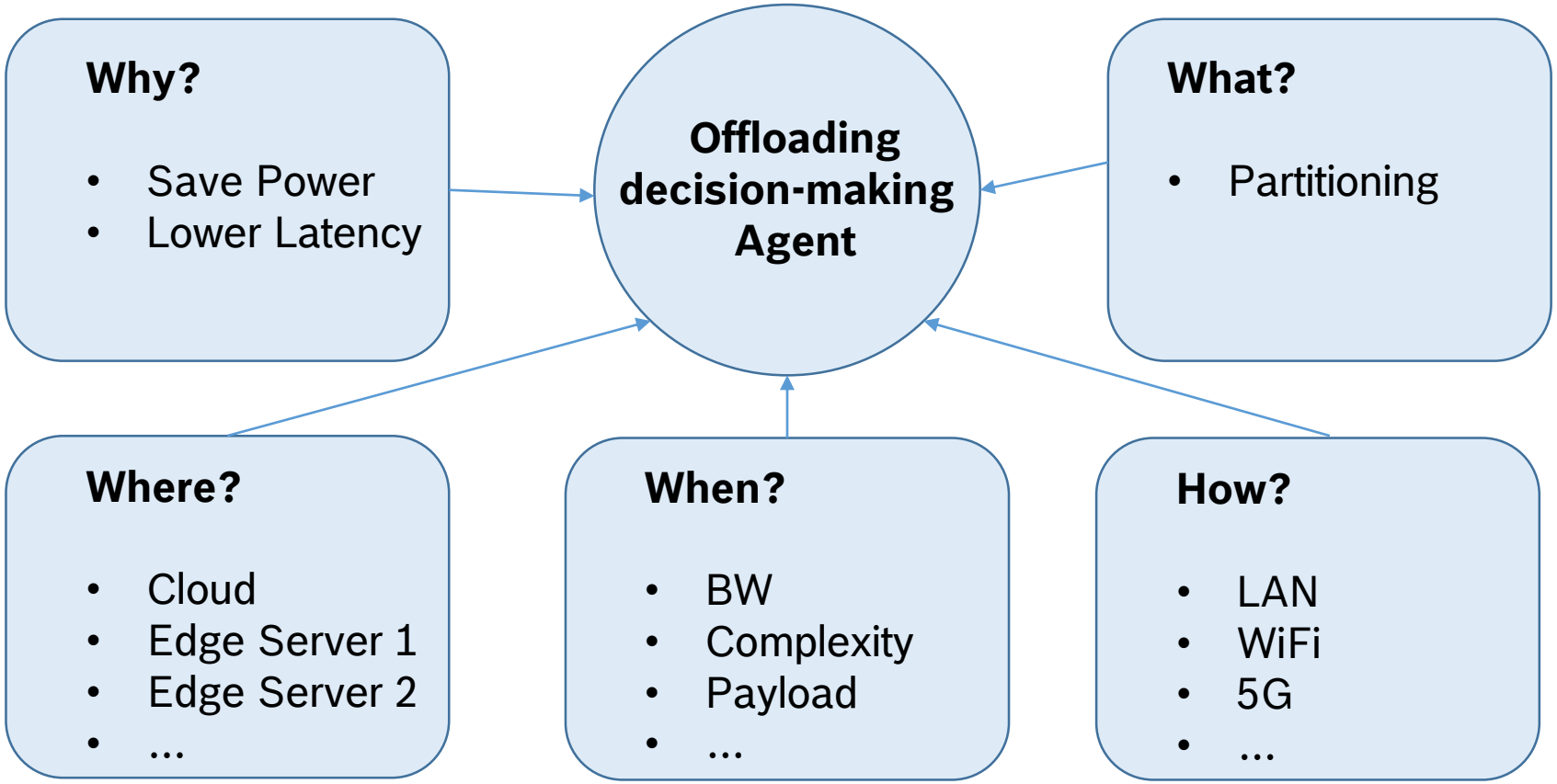



**Edge Platform**
**Redundant Services**
**Live Service Migration**
**Dedicated Orchestration**

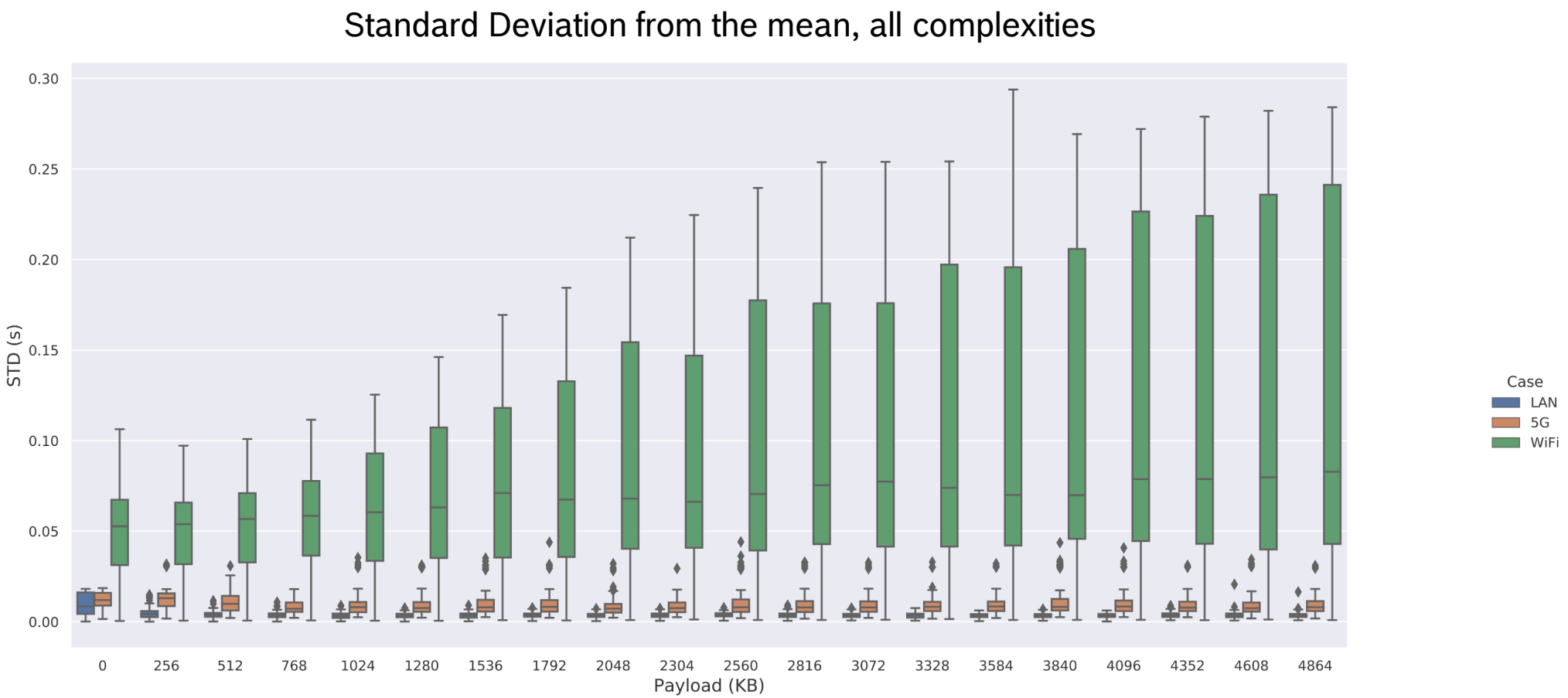
**5G Platform**
**Guaranteed Bandwidth**
**Stable Latency**
**Dedicated Service**

**Video Application**
**Short Latency < 100 ms**
**High Data Rates > 70 Mbps**
**Complex Processing**

# Smart Factories: TOMORROW
## AI-based Offloading Decision Making



# Smart Factories: TOMORROW
## AI-based Offloading Decision Making



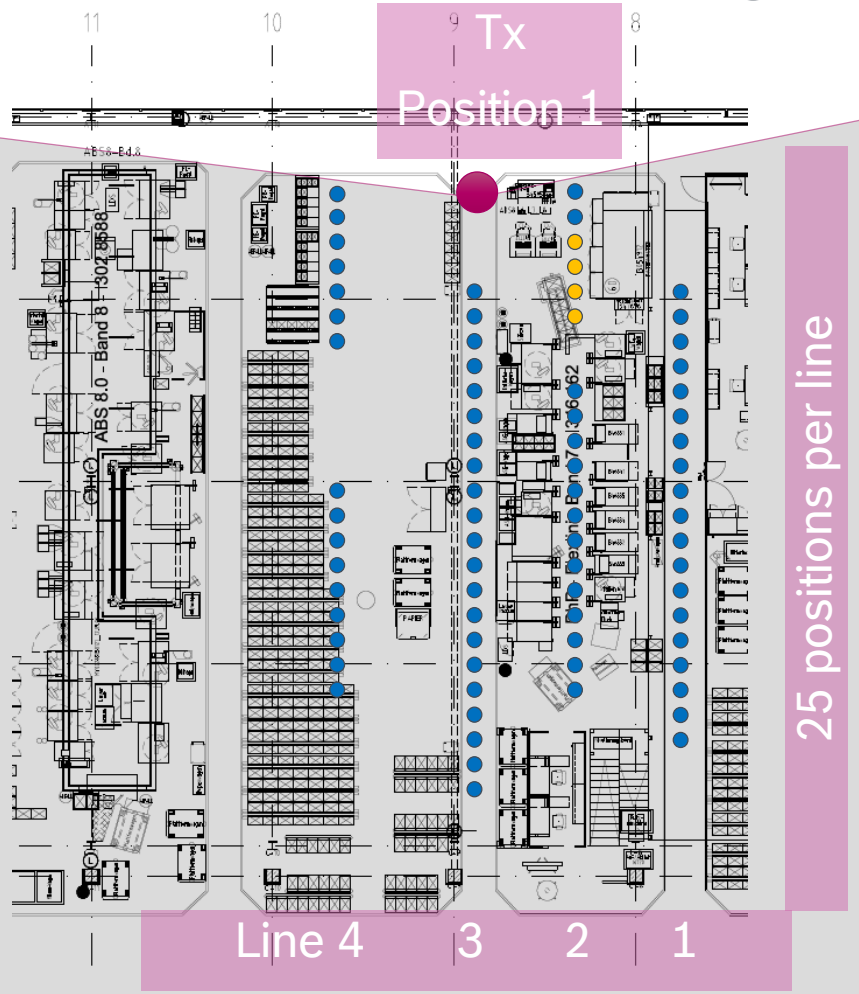
# Smart Factories: TOMORROW
## Mobile Communication: Use Case Requirements

| Use case (high level) | | Availability | Cycle time | Typical payload size | # of devices | Typical service area |
|---|---|---|---|---|---|---|
| Motion control | Printing machine | >99.9999% | < 2 ms | 20 bytes | >100 | 100 m x 100 m x 30 m |
| | Machine tool | >99.9999% | < 0.5 ms | 50 bytes | ~20 | 15 m x 15 m x 3 m |
| | Packaging machine | >99.9999% | < 1 ms | 40 bytes | ~50 | 10 m x 5 m x 3 m |
| Mobile robots | Cooperative motion control | >99.9999% | 1 ms | 40-250 bytes | 100 | < 1 $km^2$ |
| | Video-operated remote control | >99.9999% | 10 – 100 ms | 15 – 150 kbytes | 100 | < 1 $km^2$ |
| Mobile control panels with safety functions | Assembly robots or milling machines | >99.9999% | 4-8 ms | 40-250 bytes | 4 | 10 m x 10 m |
| | Mobile cranes | >99.9999% | 12 ms | 40-250 bytes | 2 | 40 m x 60 m |
| Process automation (process monitoring) | | >99.99% | > 50 ms | Varies | 10000 devices per $km^2$ | |

Source: 5G-ACIA www.5g-acia.org

See Acknowledgements for pictures used on this slide

# Smart Factories: TOMORROW
## Channel Measurements





Measured resources:

- 3.5 – 10 GHz
- 30-37 GHz
- 57-64 GHz

BW: 6.75 GHz (x1, x5, x9)

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# SMART FACTORIES: THE DAY AFTER TOMORROW

https://youtu.be/ISk64bJ35yM

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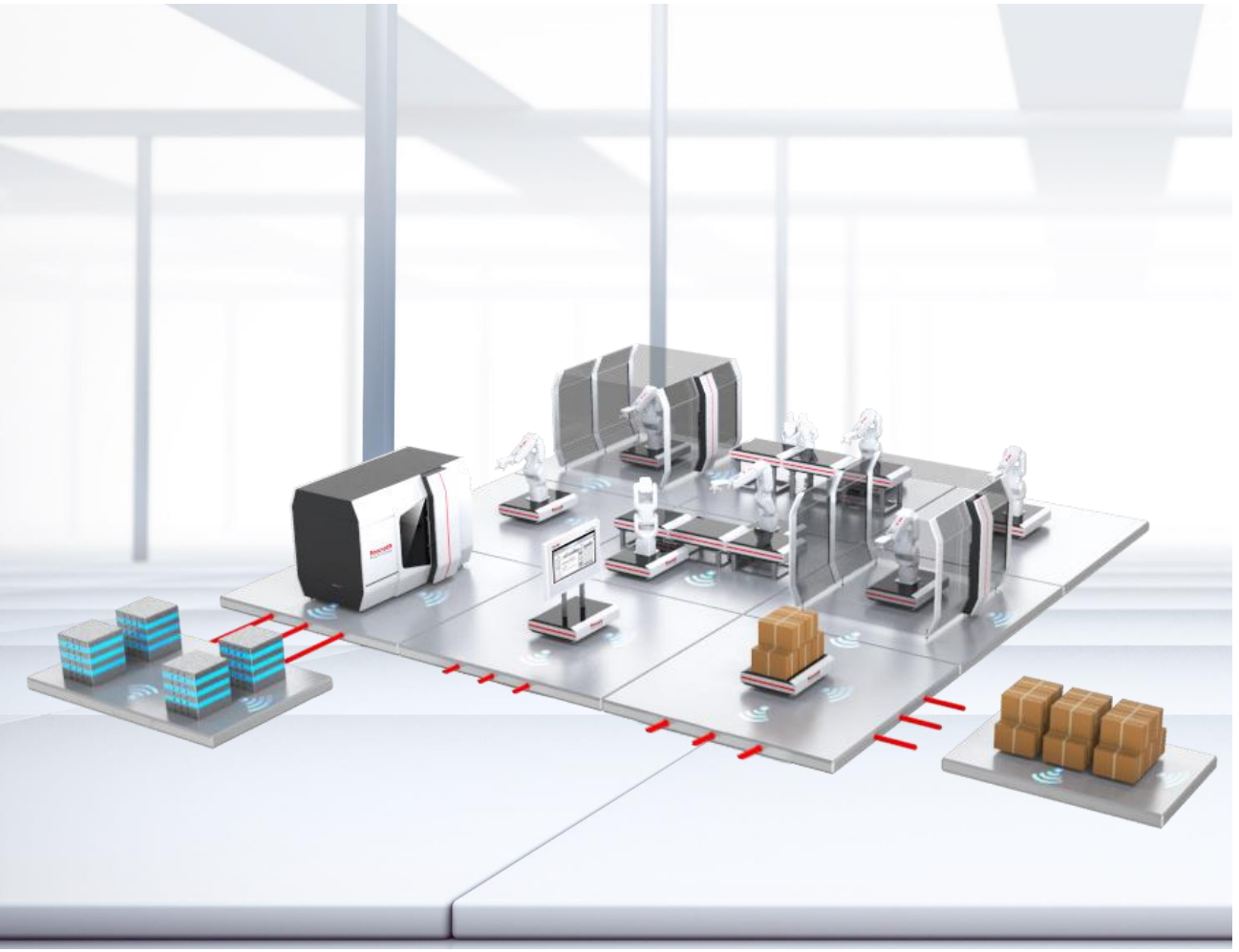
# Smart Factories: THE DAY AFTER TOMORROW



## Advances

- Highly flexible, variable production
- Factory-as-a-service
- Lot size 1 at large-scale conditions
- Very high productivity
- Low invest and low cost
- Complete automation
- Highest connectivity, unlimited compute
- Very high mobility

## Challenges

- Integration of novel technologies into brown field:
  - Connectivity: THz, OWC
  - Compute: Quantum computing
- Very short product life cycles
- Very low communication cycle times and expected jitter
- Highly volatile requirements on communication and compute infrastructures

# Smart Factories: THE DAY AFTER TOMORROW

## AIoT – AI-enabled IoT

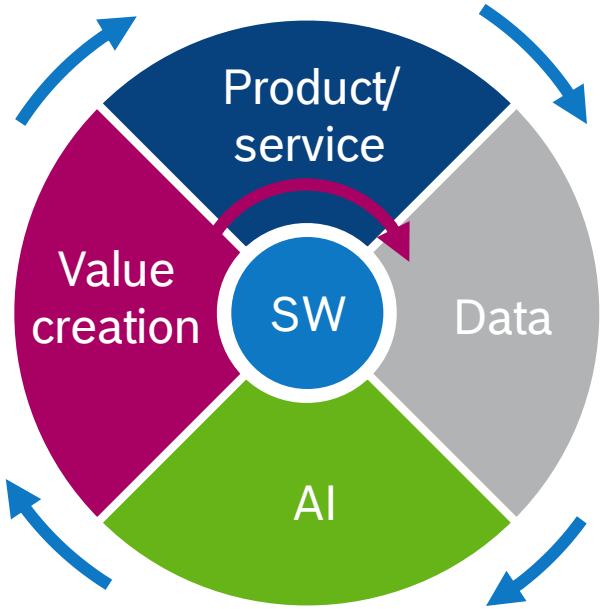
### Key enablers

- **Data ownership & policies**
- **Data architecture**
- **Digital twin**
- **Data quality**
- **Data lifecycle**
- **AI development**

### Key tasks

- leverage data using AI
- organize data
- process data
- collect data

### AIoT value creation cycle




Quick continuous improvement through data-driven, agile feedback cycles

# Acknowledgements and Sources

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